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SIGNAL TRANSMISSION SYSTEM FOR A MEASUREMENT DEVICE

This invention relates to measurement device for use on
coordinate measuring apparatus, such as a coordinate
5   measuring machines (CMMs) machine tools, manual co-
ordinate measuring arms and inspection robots. More
particularly, it relates to signal transmission systems
for such measurement devices.

10   A trigger probe for determining the position of a
workpiece is described in US Patent No. 4,153,998. In
use, the probe is moved by the machine relative to a
workpiece. The probe has a deflectable stylus and
delivers a trigger signal when the stylus contacts the
15   workpiece. The trigger signal is indicated by the
probe switching from one state to another. The trigger
signal is used by the machine controller to freeze the
outputs of scales or other measuring means which
indicate the position of the probe. The position of
20   the point of contact on the workpiece surface can thus
be determined.

Especially on machine tools, it can be difficult to
wire the probe directly to the machine controller, and
25   so various wireless signal transmission systems have
been developed in the prior art. These include
inductive systems (where the signal is transmitted by
electromagnetic induction between two coils), optical
systems (where an optical emitter such as an infra-red
30   diode is provided on the probe and produces an optical
signal which is received by an appropriate receiver)
and radio systems (having a radio transmitter in the
probe and a radio receiver fixed at a convenient
location on the machine). An example of a radio system

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is shown in US Patent No. 4,119,871. An important
requirement of such probes is repeatability, i.e. that
the same result should be achieved every time a given
measurement is repeated. The mechanical position of
5   the stylus in the probes described in US Patent No.
4,153,998 is extremely repeatable in space, an instant
of production of the trigger signal always has a
definite, repeatable relationship with the instant of
contact between the stylus and the workpiece. This
10   means that accurate results can be obtained from the
probe by a simple calibration procedure.

However, the accuracy would be destroyed if the signal
transmission system were not repeatable, that is, if
15   there were an unknown, variable delay in the signal
transmission. If this occurs then the probe would
travel an unknown variable distance after the instant
of generation of the trigger signal before the machine
control is able to freeze the outputs of the measuring
20   means. There is then an error between the position of
contact and the position indicated by the frozen
outputs and this error is an unknown variable quantity
which cannot be removed by calibration. Thus, in order
to maintain overall accuracy of the probe system there
25   is the problem of ensuring that any transmissions
delays introduced by the signal transmission system are
repeatable i.e. the same delay should be introduced
every time the probe is triggered. The probe
calibration procedure mentioned above will then also
30   remove this repeatable delay caused by the transmission
system.

US Patent No. 5,279,042 discloses an analogue radio
signal transmission system for a probe in which the

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probe is provided with a transmitter for producing a
carrier signal onto which a probe signal may be
modulated. A receiver receives the probe data and
produces a probe output signal derived from the
5   transmitter data. A clock on the transmitter provides
a time standard for the whole system, the receiver uses
an oscillator with a phase comparator at its input to
ensure that the oscillator is permanently synchronised
with a clock in the transmitter. When a probe signal
10   occurs, the time elapsed between the start of a counter
cycle and the change of state of the probe is latched
in a shift register and transmitted serially.

This method has the disadvantage that as the
15   transmitter transmits a continuous signal which is
required to synchronise the transmitter and receiver
the system uses a significant proportion of the probe
battery power and thus reduces the battery life.

20   Furthermore, in a fixed frequency system, the number of
available communication channels is equal to the
limited number of frequency channels. There is
therefore the problem of receivers from other systems
which use this frequency channel intercepting the
25   transmission sent from the probe. In addition, the
presence of radio traffic may affect the transmissions.

The present invention provides a transmission system
for a measurement device for a coordinate positioning
30   apparatus, comprising:
        a first station for mounting with one of the
measuring device and the coordinate positioning
apparatus;
        a second station for mounting with the other of

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the measuring device and the coordinate positioning
apparatus;

Wherein the first and second stations communicate
using a spread spectrum radio link.

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The spread spectrum radio link has the advantage of
reducing the chance of unwanted receivers intercepting
a transmission, and increasing the chance of a
transmission getting through to the correct receiver in
10   the presence of unwanted radio traffic.

The first and second stations communicate with one
another using a spread spectrum radio link. This is a
technique which takes a narrow band signal and spreads
15   it over a broader portion of the radio frequency band.
Two types of spread spectrum radio link comprise
frequency hopping and direct sequencing. In frequency
hopping the signal is spread by hopping the narrow band
signal as a function of time. In direct sequence, the
20   signal is spread by mixing it with a special code.

The use of a periodic signal rather than a continuous
signal increases battery life.

25   The measurement device may comprise a measurement
probe, for example a touch trigger probe.

Preferably the transmission system uses a world-wide
frequency band.

30

The first and second stations may be provided with a
clock, wherein the clocks are synchronised at least
once. The first station may transmit a regular
transmission and wherein when the second station

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receives the signal it may synchronise its clock with
the first station. If a signal transmitted by the
first station is not adequately received by the second
station, the signal may be retransmitted by the first
5   station.

If the second station receives the signal transmitted
by the first station, it may transmit an
acknowledgement signal. If the first station does not
10   receive an acknowledgement signal in response to its
signal, it will re-transmit said signal. The ability
to re-transmit messages which have not been received
enables the system to be capable of operating in a
noisy environment.
15

Preferably the transmission system comprises a half
duplex link.

In the event of a measurement event, the first station
20   may transmit information relating to said measurement
event. The measurement event may comprise a touch
trigger event. The information may include data
relating to the time of the measurement event. The
first station may transmit a regular transmission and
25   information relating to the measurement event may be
transmitted in an additional transmission.

The signal transmitted by the first station contains
information relating to the measurement device, the
30   measurement device output signal in the second station
may be produced after a time delay. This time delay is
chosen so that it is long enough to allow
retransmissions of the signal within the time delay.

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A master clock is provided at one end of the
transmission system and a sliding correlator is
provided to recover the master clock. This provides a
reference for the measurement device) output signal

5   time delay (e.g. a probe trigger output time delay).
If the second station receives a signal from the first
station it transmits an acknowledgement signal, the
acknowledgement signal sent to the first station is
synchronised with the master clock. This removes the

10 need for clock recovery at the first station.

In a preferred embodiment, signals sent between the
first and second stations comprise data bits and data
bits relating to more important information are

15 provided with greater error protection than other data
bits. The data bits relating to more important
information may be provided with a higher hamming
distance than other data bits.

20 Preferably, the first station transmits regular signals
and wherein the first station has a mode and wherein
each regular signal asks if the first station should
change mode, and wherein if the first station receives
an affirmative response, it changes mode. A mode may

25 comprise a power saving mode in which the regular
signals are sent at a slower rate than the normal mode.
This minimises power consumption and is sufficient to
allow the second station to maintain synchronisation
with the first station.

30

Preferably, if the first and second stations are not
synchronised, the first and second stations will hop
between frequency channels at different rates until
second station receives the signal and synchronises

with the first station. If the second station detects
background noise above a predetermined level on the
selected frequency channel, it will change to a
different frequency channel.

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A second aspect of the invention provides a
transmission system for a measurement probe for a
coordinate positioning apparatus, comprising:
        a first station for mounting with one of the
10 measuring device and the coordinate positioning
apparatus;
        a second station for mounting with the other of
the measuring device and the coordinate positioning
apparatus;
15   wherein the first and second stations may
communicate on different frequency channels and wherein
if the second station hears significant noise on a
certain frequency channel, it will hop to another
frequency channel.
20

Preferred embodiments of the present invention will now
be described by way of example with reference to the
accompanying drawings wherein:
        Fig 1 illustrates a touch trigger probe mounted on
25 a machine tool;
        Fig 2 is a schematic illustration of the frequency
hopping and synchronisation of the first and second
stations;
        Fig 3 is a schematic illustration showing lost
30 hops and event interruptions;
        Fig 4 is a schematic illustration showing a probe
trigger and delay counters;
        Fig 5 is a schematic illustration showing
synchronisation recovery; and

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Fig 6 is a schematic illustration of the sliding
correlator in the machine station.

Fig 1 illustrates a touch trigger probe 10 mounted on a
5   spindle 12 of a machine tool. The touch trigger probe
10 has a deflectable stylus 14 with a workpiece-
contacting tip 16. The signal transmission system
comprises two stations, the probe station 18 is
connected to the touch trigger probe and is mounted to
10   a moving part of the machine tool. A machine station
20 is mounted on a stationary part 22 of the machine
tool structure and is connected to the machine tool
controller 24.

15   Data is transmitted between the probe station 18 and
machine station 20 using a spread spectrum radio link,
in this case a frequency-hopping radio communications
link, which sends discrete packages of serial binary
data.
20
Both the probe and machine stations hop between
different frequency channels roughly in synchronisation
with each other with occasional messages sent between
them to synchronise the two stations. The probe
25   station initiates each exchange of messages and
receives a reply from the machine station.

The frequency-hopping and synchronisation will now be
described in more detail with reference to Fig 2. The
30   machine station is listening for messages most of the
time whilst the probe station is in its half-on
condition most of the time (e.g. as in slots n+1 to n+3
above). When the probe station is half-on its probe
interface and microprocessor will be on and the radio

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modem will be off. The probe interface and
microprocessor each use about 2mW of power whilst the
radio modem uses significantly more power, about 120mW
when switched on. The radio modem consumes a similar
5   amount of power whether it is receiving or
transmitting. The half-on state thus minimises power
consumption of the battery powered probe system.

Fig 2 shows the probe station turning on with a small
10   settling time and then transmitting an "I'm OK" message
on frequency channel f(n). The probe station then
listens for the acknowledgement from the machine
station. The machine station which is listening on
channel f(n) receives this message, synchronises its
15   clock with the probe station and then sends an
acknowledgement back on channel f(n). Upon receiving
this acknowledgement the probe station switches back to
its half-on condition. The probe station clock
therefore acts as the master clock for the system. When
20   the machine and probe stations are synchronised, they
hop between frequency channels at the same time.

The probe station is now silent for a number of time
slots (assuming there are no probe triggers) and the
25   machine station listens on successive frequency
channels f(n+1), f(n+2) etc. Although the probe
station is not transmitting on the successive frequency
channels f(n+1), f(n+2) etc, it is still hopping
between frequency channels. Fig 2 shows an exaggerated
30   error in clocks between the probe and machine stations.
This error is small enough to allow the stations to
remain synchronised to the order of 100 silent time
slots. Thus although because of this error the machine
and probe stations hop to a new channel at a slightly

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different time, the error is small enough that there is
sufficient overlap when the probe station is
transmitting and the machine station is listening in
the same frequency channel for signals to pass between
5   the stations. This error is corrected each time the
machine station receives a message from the probe
station.

For clarity Fig 2 only shows three silent slots and
10   thus three frequency-hops are unused. The periodic
timer then prompts the probe station to transmit again
on f(n+4) and this cycle then repeats until interrupted
by some other event (e.g. a lost transmission, a probe
trigger or a probe station turn-off signal).
15

Transmissions from the probe station may not be
received by the machine station due to for example
interference. Such a situation will now be described
with reference to Fig 3. In Fig 3 settling time is not
20   shown and the effects of synchronisation of clocks and
hopping between the probe station and machine station
is assumed.

The transmitted radio packet from the probe station
25   includes probe data. For example, the probe may be
seated (S) or the probe may have triggered (T). Other
information may also be transmitted in the radio
packet, for example the condition of the battery, how
many transmissions have been attempted for this message
30   and data relating to the time of a touch trigger event.

In time slot n a successful message from the probe
station and reply from the machine station, all on
frequency channel f(n) is shown. This confirms that

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both the probe station and radio link are operating and
that the output from the machine station can be
trusted.

5   In time slot n1 the probe station transmits a message,
the machine station receives this message and sends an
acknowledgement. However the probe station does not
receive this reply for example due to interference.

10   As no acknowledgement is received the probe station
will re-transmit the message in the next time slot
n1+1. Fig 3 shows the re-transmission of the message
from the probe station in time slot n1+1. However, as
the machine station receives nothing, it does not send
15   an acknowledgement. The probe station will therefore
receive no message and so will re-transmit the message
in slot n1+2.

In time slot n1+2 everything works. The machine
20   station receives the probe station message and the
probe station receives the machine station
acknowledgement. The probe station can therefore
return to its half-on condition with its radio modem
off.
25
If however after a predetermined time the machine
station does not receive the message from the probe
station then either the radio link or the probe station
has failed and the machine station will set an error
30   output.

For the first transmission of a message, a normal radio
frequency power level is used, for example 1mW. On
subsequent re-transmissions, the radio frequency power

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level may be increased, thus increasing the chance that
the message will get through.

As there is the opportunity of re-transmission at a
5   higher radio frequency power, this enables a slightly
lower radio frequency power to be used for normal
transmissions. This has the advantage of minimising
radio traffic and extending battery life.

10   In time slot n2 in Fig 3, a probe trigger occurs. An
out of sequence transmission must be sent by the probe
station to the machine station as soon as possible.
The probe station transmits a probe trigger message to
the machine station in the next time slot n2+1. As
15   before, the machine station acknowledges the message.
A probe trigger message outranks the periodic update
and thus when a probe trigger occurs data relating to
the probe trigger will be included in the data packet
sent in the next transmission.
20
As illustrated in Fig 4, when a probe trigger occurs a
timer in the probe begins counting from zero. The
value of this timer t1 is latched at the beginning of
the next time slot n+1. This value t1 is transmitted
25   from the probe station to the machine station in a
transmission in the next time slot n+1.

The machine station decodes this value t1 from the
transmitted message and computes a value tk-t1 where tk
30   is a constant. The machine station loads its own
countdown counter with the value tk-t1. At the end of
the time slot n+1 the countdown counter is started and
when it reaches zero the probe status output changes to
triggered.

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The time delay between the probe trigger and the
machine station probe output will therefore be
t1+ts+tk-t1 = ts+tk, where ts is the time of one time
slot. This value ts+tk is constant. The delay between
5   probe trigger and machine station probe output is
therefore always the same.

The time constant tk is selected to allow re-
transmission of the message if the first transmission
10   (i.e. in time slot n+1) fails. In Fig 4, time slots
n+2,n+3 and n+4 are available for re-transmission of
the probe trigger message. For a re-transmission a
correction is applied to tk-t1 equal to the time taken
by the number of unsuccessful transmissions. This
15   correction will be the number of retries done
multiplied by the length of a single time slot. The
message transmitted by the probe station will include
data which indicates which try it is (1st, 2nd, 3rd,
etc). Alternatively the probe station can (re-)latch
20   the probe station counter at the beginning of each time
slot in which a message will be sent. (This value
will be t1 + ts for a message sent in slot n+2, t1 +
2*ts for a message sent in slot n+3 and so on.) Thus
whichever time slot the message is successfully
25   transmitted in, the total time delay will be constant
(=ts+tk) between the probe trigger and the machine
station probe status output.

For the probe station and machine station to
30   communicate they must both be set to the same frequency
channel at the same time. To achieve this the probe
station frequency channel controller and the machine
station frequency channel controller must be
synchronised. This is achieved by a synchronisation

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recovery/find and collect process described below with
reference to Fig 5.

The probe station is shown hopping between frequency
5   channels at normal speed (e.g. one hop per millisecond)
and the machine station is shown hopping at a much
slower speed (e.g. one hop per 50 milliseconds). The
probe station transmits in every time slot (n,n+1,n+2
etc) and then listens for a reply before hopping to the
10   next time slot. The probe station transmission
contains the ID number of the probe and includes a
request for synchronisation and acknowledgement of the
message. The machine station listens for many probe
station time slots and occasionally changes to a
15   different frequency channel. In time slots n,n+1 and
n+2 in Fig 5 the probe station is shown transmitting on
successive different frequency channels whilst the
machine station listens. However whilst the machine
station is on a different frequency channel to the
20   probe station it receives nothing.

In time slot n1-4 the machine station is shown hopping
to a new frequency. Meanwhile the probe station
continues hopping frequency channels and transmitting.
25   In slot n1 the probe station and the machine station
are on the same frequency channel and the machine
station hears the message from the probe station and
synchronises its time slot clock to the probe station.
The machine station is now synchronised with the probe
30   station and a periodic handshake to maintain
synchronisation can now occur. The machine station
acknowledges the message from the probe station in the
time slot n1.

15

Usually the acknowledge message from the machine
station will be received by the probe station. However
Fig 5 illustrates what happens if the probe station
fails to hear the acknowledgement. In time slot n1 the
5   machine station transmits an acknowledgement but
although the probe station is listening it does not
receive the acknowledgement. The probe station hops to
the next time slot n1+1 and again transmits its
message. As the machine station is synchronised it
10   will be listening on the correct frequency channel in
time slot n1+1 and will thus hear the message from the
probe station. The machine station will synchronise
its clock again and will acknowledge the message again.
The probe station message in slot n1+1 is effectively a
15   re-transmission as shown in Fig 3.

During the process of synchronisation recovery, if the
machine station hears significant noise on a certain
frequency channel, it will immediately hop to another
20   frequency channel rather than wait on the frequency
channel where background noise may swamp any
transmission from the probe station.

It is desirable to be able to turn on the probe station
25   via a radio message from the machine station. Whilst
waiting for this radio turn-on the probe station is in
its radio standby mode in which it consumes
substantially less battery power than when it is in its
operating mode.
30
The probe station radio standby mode is similar to the
periodic update, although the time slots may be wider
and the cycle time longer, i.e. slow hopping between
frequency channels.

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Most of the time the data exchange will consist of the
probe station transmitting its ID number and asking it
if should be turned on, whilst the machine station
replies that it is not needed. As with the operating
5   mode the machine station is synchronised to the probe
station during this exchange. If the probe station
does not receive an acknowledgement from the machine
station it will re-try to transmit the message in
subsequent time slots in different frequency channels.
10

If it is required to turn-on the probe station, the
machine station will reply "turn-on" and change to
operating mode. The probe station will then switch to
the operating mode. In the operating mode the machine
15 station will maintain synchronisation with the probe
station as described above.

Turn-off will require an exchange of messages as the
turn-off request may come from the machine station or
20 alternatively from the probe station (for example a
time out). Following turn-off both probe and machine
stations will return the synchronised slow hopping
described above.

25 As discussed earlier, the radio signals between the
probe and machine stations consist of message packets
of serial binary data. Each message contains a header
which includes probe station identity data, or address,
needed to enable the machine station receiver to
30 recognise whether the message is intended for that
receiver and to synchronise a clock in the machine
station to the probe station clock.

The machine station uses a correlator to recognise the

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incoming message header.

Fig 6 illustrates the sliding correlator used in the
machine station. A radio frequency receiver and de-
5   modulator 26 receive radio signals transmitted from the
probe station and output a serial stream of received
data into a large shift register 28.

On each pulse of an oversampling clock 30, the incoming
10   serial data stream is sampled and its value (1 or 0) is
loaded into the shift register 28. Simultaneously the
contents of the register are shifted right 1 bit, the
last bit being shifted 'off the end' and lost.

15   A target word is held in a separate target register 32.
The entire shift register contents are continuously, in
parallel, bit to bit compared with the target register
contents by an array of exclusive-or (EOR) gates 34.
One EOR gate is used per bit of the shift register and
20   the outputs of the EOR gates are added at an Adder 36
to determine the number of bit-matches detected.

The number of bit matches detected is then fed to a
comparator 38, where it is compared with the required
25   number of matches threshold 46, which is typically
greater than 95%, to determine the correlation detected
binary output 42.

The target word is programmable, thus the correlator
30   can be set to detect different desired bit sequences.
In particular, the target word is set to the expected
header sequence which will be sent from the transmitter
(i.e. the acquired partner probe station).

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In a typical system the header could be a 32 bit word
with a data rate of 1 bit / microsecond. The
oversampling clock might run at 10 times the data rate,
i.e. 10MHz and the threshold could be 95% match. Thus

5   the shift register would contain 10 x 32 = 320
flip-flops, and the EOR gate array would contain 320
EOR gates. The outputs of the 320 EOR gates would be
fed to the adder, which would output a number between 0
and 320 to the comparator. To achieve a 95% or better

10   match, the threshold would be set at 320 x 0.95 = 304
bits. Thus if 304 or more bits in the shift register
matched their targets from the target word, the
correlation detected output will be True, otherwise it
will be False. This test is done and the correlation

15   detected output updated on every pulse of the
oversampling clock, i.e. every 100 nanoseconds.

The advantage of this system is that clock recovery is
only required at one end of the half duplex link.   The

20   master clock is provided at the probe station. At the
machine station, the sliding correlator is used to
recover the clock data from the messages transmitted
from the probe station. The sliding correlator provides
a reference for the probe trigger time delay and allows

25   acknowledgement messages to be sent already
synchronised, thus removing the need for clock recovery
at the master end of the link (i.e. at the probe
station).

30   There are two main types of possible correlator errors.
The correlator may fail to identify a transmitted
message, described above or a correlator may report a
match when no message has been transmitted.

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If the machine station falsely believes that it has
received a message from the probe station, this will
result in loss of the synchronisation of the machine
station clock, failure of the radio link and an error
5   message being produced. The probe station only listens
for a machine station acknowledgement immediately after
it has sent a message and the machine station
acknowledgement is thus expected within a very narrow
timeslot.

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When in the operating mode, a failure will occur when
noise imitates a machine station acknowledgement and
thus prevents the probe station from re-transmitting
the message. However the probe station is only
15 vulnerable to this error when it is waiting for an
acknowledgement which doesn't come.

The transmitted message contains several different
items of information, such as probe station address,
20 probe status (i.e. seated or triggered), timestamp
(i.e. time of probe trigger) and battery status. Some
of these items have high importance, such as the probe
station address and the probe status. The timestamp
has high importance if the probe status is 'triggered'
25 but is otherwise not important. The battery status has
low importance.

In order to optimise error protection of the
transmission, the most important data bits of the
30 message are encoded with a large hamming distance.
This allows small numbers of bit errors to be corrected
and larger numbers of bit errors to be rejected. A
higher hamming distance has the advantage of allowing
some error correction but has the disadvantage that it

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increases transmission time. Less important data is
provided with a lower degree of error protection, for
example multiple bit error detection using a cyclic
redundancy check.

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For example, the probe station address and probe status
data may be encoded with a hamming distance of 6, which
could allow 1 bit error correction and 4 bit error
detection. The timestamp and battery status may be
10 encoded with a lower hamming distance of 4 which could
provide 3 bit error detection.

The information required during the periodic
transmissions (probe station address and probe status)
15 thus has higher error protection than other information
in the message. There are several empty timeslots
between each periodic transmission which are available
for re-transmissions if the transmission fails.
However, if all these timeslots are used up by
20 unsuccessful re-transmissions, an error signal will be
produced and the whole system will stop. It is
therefore advantageous to have a high reliability
periodic transmission, leaving the empty timeslots as a
safety buffer.

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In the event that the probe status is 'triggered', the
timestamp data becomes important. This data has a
lower hamming distance and will be retransmitted if an
error is detected.
30 There may be, for example, about 50 periodic
transmissions per second and about 1 trigger per
second. It is therefore more important to avoid re-
transmissions on the periodic transmission than the
trigger signal.

The system of using longer hamming distance codes for
the more important data has the advantage that it
reduces the number of retransmissions required for the
periodic transmissions. As the lower priority data is
5   given lower hamming distance codes, the transmission
time is reduced. The radio traffic and battery life are
thus also reduced.

A feature of the present invention is that once the
10 probe station is in place, it will only communicate
with its partnered machine station. This enables
different systems to operate simultaneously in the same
environment without interfering with one another. A
partnering process transfers the probe stations unique
15 32 bit ID to the machine station. In a preferred
embodiment of this process, when a probe is put onto a
machine, the probe stations enters a 'Send Acquisition'
mode. In this mode it transmits a message which
includes its unique ID and a 'header' which is
20 recognised by the machine stations. This message is
transmitted periodically, for example once every 1ms
across all channels in its hopping pattern. In a next
step, the machine station is powered on and in an
initial time period, for example 10 seconds, it is
25 receptive to the 'Send Acquisition' signal sent by the
probe station. When the machine station receives the
transmission in which it recognises the 'header', it
reads the ID. The machine station saves the ID into
its memory in the form of an EEPROM (electrically
30 erasable programmable read only memory) and sends an
acknowledgement back to the probe station which
contains the same ID. If the probe station
successfully receives an acknowledgement (without
errors) containing its own ID, it stops the 'Send

Acquisition' process. The probe and machine station
are now successfully partnered and the machine station
will only communicate with the probe station having
this ID.

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When the probe and machine stations are partnered (i.e.
have the same ID), they will have the same channel
hopping pattern and thus will be able to communicate
whilst channel hopping.

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The probe and machine stations of the transmission
systems may transmit signals using worldwide licence
free radio frequency bands. Examples of such bands are
2.4GHz and 5.6GHz. An advantage of this is that probe

15 and machine stations may be set to function within
these frequency bands during manufacture and then the
same version of the probe may be used anywhere in the
world.

20 In the above embodiment, the probe station sends out a
regular transmission to the machine station. However
an alternative would be for the machine station to send
out a regular transmission requesting information and
in response the probe station recording information

25 (i.e. measurement and time information) and
transmitting it to the machine station.

The above embodiment describes a regular transmission
in which the probe and machine stations synchronise and

30 an out of sequence event driven transmission which
contains data about the touch trigger event. However,
it is possible to include data relating to the touch
trigger event in the regular sequence of transmissions
and thus eliminate the requirement for out of sequence

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event driven transmissions. In this case, the data
will need to contain information about the time of the
touch trigger event.

5   This invention is not limited to touch trigger probes.
This transmission system is also suitable for use with
scanning probes. In this case the regular transmissions
will include data relating to probe deflection and the
time of that probe deflection.

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Likewise, the transmission system is suitable for other
measurement devices for use on coordinate positioning
apparatus such as machine tools and coordinate
measuring machines. A ball bar device is used for

15   performing a calibration operation on machine tools and
coordinate measuring machines and is described in US
patent 4435905. The device comprises an elongate
telescopic bar provided with a ball at each end. In
use, each of the balls is retained in a socket provided

20   on the machine spindle and table respectively and the
arm is then driven in a circular path about the centre
of the ball retained in the socket on the table. A
single axis transducer provided on the bar measures any
variation in the centre-to-centre spacing of the balls,

25   and thus determines the extent to which the tool holder
path varies from a circular path. Data from the single
axis transducer is relayed to the machine control via a
cable but this has the disadvantage that it limits the
number of rotations possible with the ballbar. By

30   using the transmission system of the present invention,
the transducer output and corresponding data may be
transmitted in the radio signal, thus removing the need
of the cable and allowing the ballbar to make several
continuous rotations. This transmission system may be

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used on other measurement devices, such as temperature
probes.

Although the above embodiment describes use of
5   frequency hopping, other types of spread spectrum radio
link are suitable for use in the invention, for example
direct sequence.